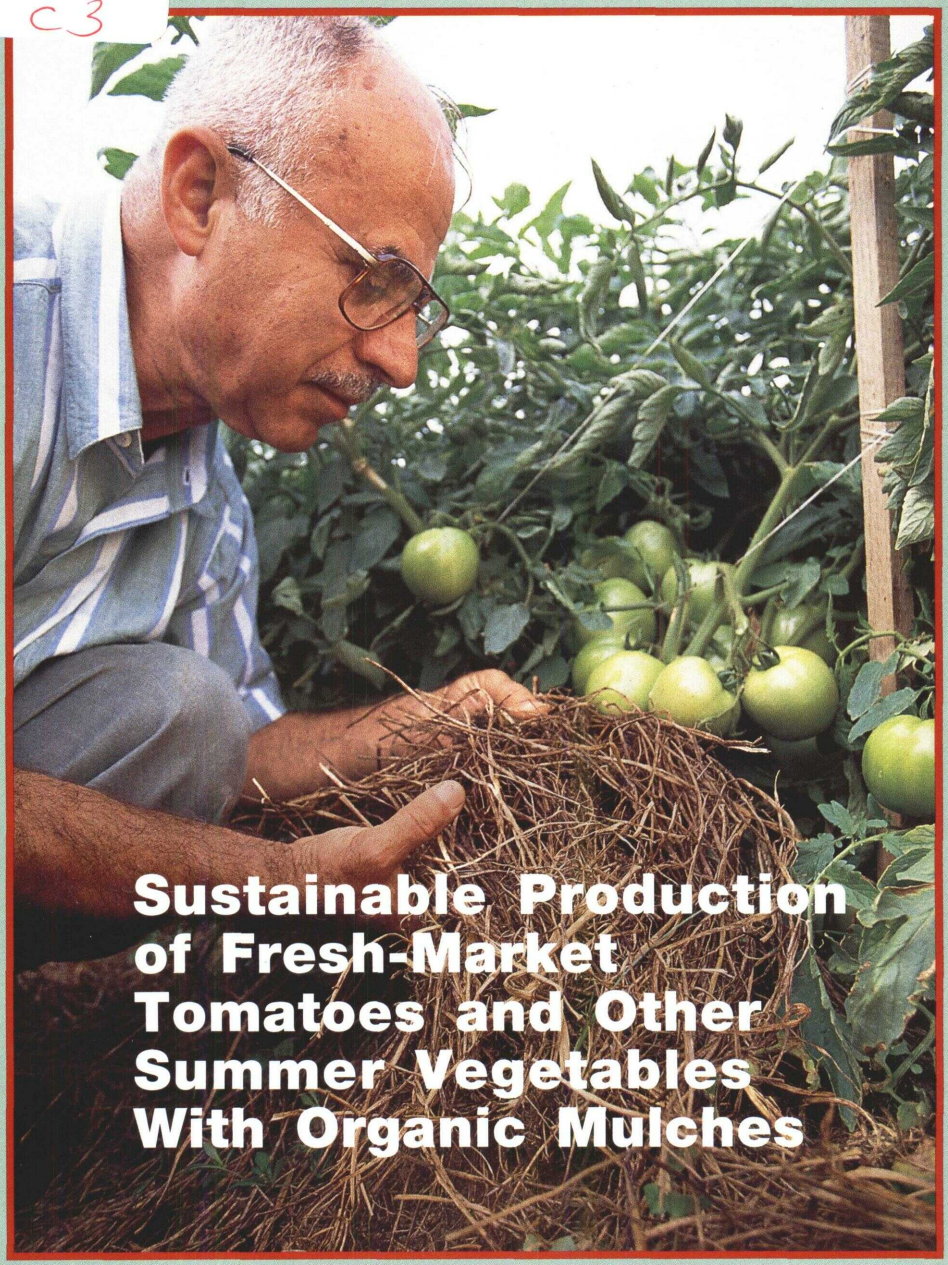

Sustainable Production of Fresh-Market Tomatoes and Other Summer Vegetables With Organic Mulches

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While supplies last, single copies of this publication may be obtained at no cost from Dr. Abdul-Baki at the address above.

Research supporting these findings was conducted at the USDA–ARS Beltsville Agricultural Research Center in Beltsville, Maryland, and with growers on private farms as a contribution to the Sustainable Agriculture Program.

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This publication reports research involving pesticides. It does not imply that uses discussed here have been registered. All uses of pesticides must be registered by appropriate state or Federal agencies or both before they can be recommended.

Cover photo. Hairy vetch mulch provides a thick residue that releases nutrients and suppresses growth of weeds.

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Sustainable Production of Fresh-Market Tomatoes and Other Summer Vegetables With Organic Mulches

SUSTAINABLE AGRICULTURE

Aref A. Abdul-Baki and John R. Teasdale

The alternative production system described in this bulletin uses the winter annual legume hairy vetch (*Vicia villosa L.* Roth) both as a cover crop and as a mulch in a sustainable tomato production system. As a cover, vetch serves to fix nitrogen, recycle nutrients, reduce soil erosion and compaction, and add organic matter to the soil. When converted to a mulch, the residue reduces weed emergence, increases organic matter content, reduces water loss from the soil, and acts as a slow-release fertilizer.

Research on this mode of production was originally confined to growing tomatoes in stands of hairy vetch. However, within a few years, the underlying concept demonstrated a great deal of promise. Once a grower masters the principle of growing tomatoes in hairy vetch, the concept can easily be modified to suit other summer crops and regional growing conditions. A surprising number of options have met with success. Selected direct-seeded summer vegetables, like sweet corn, snap beans, and pumpkins, can be grown effectively. Alternate cover crops can be selected and even seeded in beneficial mixtures to suit local growing conditions.

This publication first describes the basics of the original system: how to establish a stand of hairy vetch, convert it into a mulch, and nurture young

tomato plants in the mulch. Once you comprehend the process, consider modifying it to grow other summer vegetables, first on a small scale. Or try customizing the cover crop to suit your climate or soil condition. These possibilities are discussed in a later section, "Customizing the Basic System."

Recommended Cover Crops

Your choice of cover crop species should take into consideration factors such as its winter-hardiness, efficiency in fixing nitrogen and producing biomass, and the length of the growing season. Table 1 lists properties of winter annual legumes tested in Maryland.

Of the winter annual legumes, hairy vetch is the most adaptable and produces consistently high

Table 1. Winter annual legumes tested in Maryland

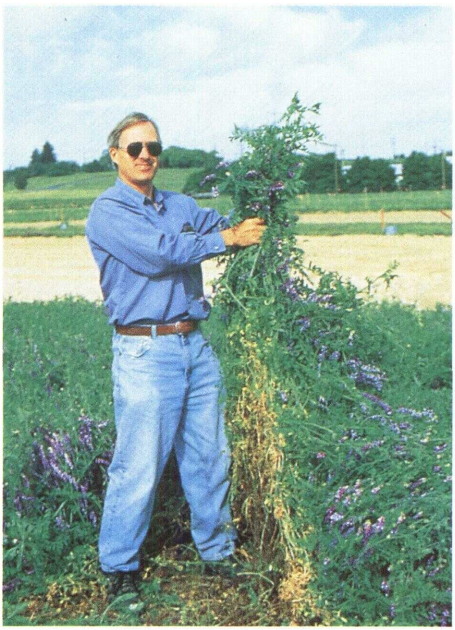
Cover crop	Best variety	Vigor	Winter hardiness	Time of maximum growth	Nitrogen content (%)
Hairy vetch	—*	Excellent	Excellent	May	4.0
Bigflower vetch	Woodford	Excellent	Excellent	May	3.5
Common vetch	Vantage	Good	Fair	May	3.5
Crimson clover	Chief/Dixie	Good	Good	April	2.5
Subterranean clover	Mt. Barker	Variable	Fair	May	3.0
Arrowleaf clover	Yuchi	Good	Fair	June	3.0
Austrian winter pea	—	Good	Fair	May	3.5
Berseem clover	Bigbee	Good	Poor	June	3.0

*— = no varieties.

amounts of nitrogen and biomass. Common vetch, subterranean clover, arrowleaf clover, Austrian winter pea, and berseem clover are not as winter hardy in Maryland as hairy vetch, bigflower vetch, or crimson clover. Bigflower vetch seed is difficult to obtain. Crimson clover provides excellent biomass for mulching and attracts beneficial insects but does not have as high a nitrogen content as hairy vetch.

Establishing the Cover Crop

Prepare your seedbeds in late summer but early enough to allow the cover crop to get established before winter (about 2 months before winter sets in). Form permanent beds—5 feet wide and 6 inches high—that can be used for more than one production season, and seed them with the winter annual cover crop.



Hairy vetch should be seeded at 25 to 40 pounds per acre. Inoculation of seeds with the proper rhizobium immediately before seeding is necessary only if the vetch has not been previously seeded in the field. In a firm seedbed,

Figure 1. **Hairy vetch makes an excellent cover crop because of its broad adaptability, fast growth, high efficiency in fixing nitrogen, and production of high-quality biomass for mulch.**

place the seed just below the soil surface, using a forage or grass seeder. Hairy vetch emerges within 1 week. The seedlings grow 5 to 6 inches high and establish a mat over the ground before winter. During subfreezing temperatures, plants can be expected to turn purple and become prostrate, but they will resume growth early in spring. When it is time to transplant your tomatoes to the field, the vetch plants have already attained 4 to 5 feet in length (fig. 1); however, because of their creeping growth habit, they lodge and form a thick stand about 2 feet high.

Between October and May, a vetch cover crop produces 3,000 to 5,000 pounds of dry matter per acre and fixes about 120 to 200 pounds of nitrogen per acre, an amount that can support the growth of the upcoming tomato crop without supplemental commercial nitrogen (table 2). Vetch also accumulates an appreciable amount of phosphate, potassium, and micronutrients.

Table 2. Biomass and nutrient content of cover crop mixtures at Beltsville, Maryland

Cover crop	Biomass	Nutrient		
		Nitrogen	Phosphorus	Potassium
	lb/acre			
Hairy vetch	4,036	125	18	132
Hairy vetch + rye	6,054	138	18	170
Hairy vetch + rye + crimson clover	7,366	148	19	166

Note: Figures are averages of 1995 and 1996 data.

Converting the Cover Crop Into an Organic Mulch

The cover crop produces most of its growth during the month before the tomatoes are transplanted, so it should be allowed to grow until immediately before the transplanting. When it's time to convert the cover crop into a mulch, there are three options.

1. *Chemical kill* with a contact herbicide.

2. *Mechanical kill* by mowing or rolling. For mowing, a high-speed flail mower, which cuts the plants 2 to 3 inches above the bed surface, is recommended to form a uniform cover that controls soil erosion and inhibits weed emergence (fig. 2). A high-speed mower is essential;

Figure 2. **A high-speed flail mower converts the cover crop to a mulch without disturbing the soil.**

Figure 3. **A home-made roller can kill the cover crop and convert it into a mulch.**

a lower speed mower, such as a sickle bar, tangles in the vetch vines, especially when the biomass is high.

For small areas, such as a home garden, you can manually cut the vetch plants or pull them out by the roots and spread them to cover the bed.

Recently, a new method was found to kill the vetch—a roller (fig. 3). A cylindrical roller, 15 to 20 inches in diameter, with bars along the surface, damages the plants without chopping them or pulling up their roots. Plants that are rolled decompose slower than those which are mowed, so they suppress weeds longer. The weight of the roller can be adjusted by filling the cylinder with water. This new method needs further evaluation.

3. *Plowing* the hairy vetch vines into the bed with a rototiller or a similar piece of equipment

to form green manure. This alternative offers two advantages—rapid decomposition of the vetch and nitrogen release. This method may be preferable in areas with too little summer rainfall to adequately break down a surface mulch, although you lose some benefits of a surface mulch—erosion control, soil moisture retention, improved water infiltration, improved soil structure, and weed suppression.

Planting the Tomato Crop

For large fields, commercial transplanters of varying sizes and capacities are available that are designed to operate in thick organic mulches (fig. 4). They can be equipped with coulters that cut and loosen a narrow band in the bed with minimal interruption to the mulch layer, although the coulters can tangle in the vetch vines if not set properly. Transplanters can also be equipped with spades to open a hole, deliver a dose of

Figure 4. **Transplanting tomatoes into hairy vetch mulch using no-till transplanters.**

liquid fertilizer, set the plant at the right depth, and press the soil firmly around it. It is important to firmly set the root ball of each transplant in the underlying soil, not in the mulch layer. Recommended spacing between plants within the row is 16 to 20 inches, depending on plant vigor and variety.

A hand planter (also called a tree planter) can be used for manual planting. Insert the planter into the soil to a depth of 4 or 5 inches and move it back and forth once to open a wedge-shaped hole 4 inches deep by 2 inches wide. Insert the transplant into the hole, press the soil around it, and reposition the mulch around the plant.

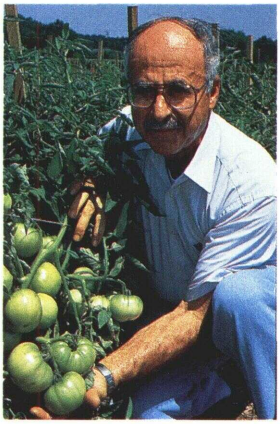
Whether transplanting manually or mechanically, avoid walking on the beds to prevent soil compaction and maintain mulch uniformity. Disruption of the mulch during any operation will promote weed growth and moisture loss.

Managing the Tomato Crop

Crop management should focus primarily on practices that result in a high yield of a high-quality, uniform product—that is, providing optimum amounts of water and nutrients and controlling weeds and pests throughout the growing season (fig. 5).

Water management is critical for producing high-quality tomatoes. Short dry spells may delay maturity, reduce yield, and lower quality. Excessive water, especially in soils with poor drainage, reduces plant growth and increases the incidence of diseases.

Figure 5. **Tomato plants grown in hairy vetch mulch are vigorous, healthy, and high yielders.**



Trickle irrigation is particularly effective when used with mulches. It conserves water by applying small amounts directly to the plant root zone, and you can use the system to apply fertilizer as often as needed. It has the added advantage of reducing weed growth in areas of the field that remain dry.

A trickle system must be installed immediately after planting so the transplanted plants do not face moisture stress conditions. Install the trickle irrigation lines on top of the vetch mulch and 3 to 4 inches from the tomato row with the emission pores toward the ground. They should be fixed in place with U-shaped wires.

The frequency of irrigation depends on soil type, temperature, plant size, and quantity of water applied at each irrigation. Generally, small quantities of water applied more frequently are preferable to large quantities applied less frequently. Excessive watering tends to wash nutrients downward to depths below the root zone and to reduce fertilizer use efficiency. It is advisable to flush the trickle system monthly with chlorinated water to keep the emission pores from clogging.

Application of fertilizers through the trickle system is most efficient, delivering only small

amounts at a time. Best results are achieved when fertilizer is applied at least four times per season. When tomatoes are grown in a vetch mulch, the demand for commercial fertilizers in general, and for nitrogen in particular, lessens. As a rule, tomatoes grown in a hairy vetch mulch produce about 85 percent of maximum yields without any addition of commercial nitrogen fertilizer (fig. 6). Adding about one-half the recommended nitrogen rate results in maximum yields. Note, however, that excessive nitrogen can lead to higher losses into the environment. Other nutrients such as phosphorus and potassium should be added at the time of bed preparation according to soil test results.

Staking and tying up the plants is highly recommended for fresh-market tomatoes. While staking does not increase yield, it does facilitate manage-

Figure 6. **Nitrogen requirements by fresh-market tomatoes, variety Sunbeam, grown in black polyethylene and hairy vetch mulches.**

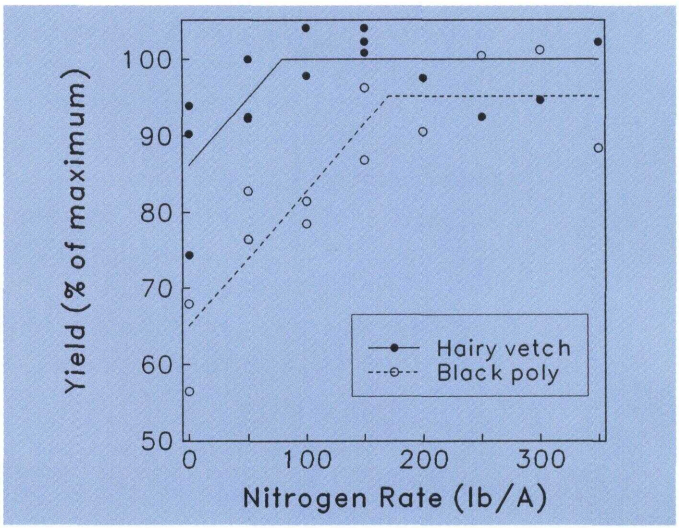


Figure 7. **Staking raises the fruit off the ground, exposes the plant to light, and facilitates field operations.**

ment and improve fruit quality. So, within 2 weeks of planting, stake every other plant and support the plants with twine woven from stake to stake. Usually, three rows of twine are needed to support full-grown plants (fig. 7).

Weed control is essential for maximum yields and high quality. Generally, hairy vetch will not regrow if mowed at flowering time. The optimum time for transplanting tomatoes (when the vetch should be mowed) often is 2 to 3 weeks ahead of vetch flowering. This early mowing does not kill the vetch, and it soon regrows in a weedlike fashion, overgrowing the tomato plants in 3 to 4 weeks. Don't worry. The postemergence herbicide treatment we are about to describe will solve the regrowth problem.

The vetch mulch suppresses weed emergence for the first month after mowing. As the vetch vines decompose, weed seedlings will eventually

Figure 8. **Fresh-market tomatoes growing in hairy vetch mulch *(top)* and polyethylene mulch (*bottom*).**

emerge through the mulch and require control with postemergence herbicides. An application of 0.5 pound of active ingredient of metribuzin per acre will probably be needed approximately 3 to 4 weeks after transplanting to control the vetch regrowth and the emerging weeds, whichever

appears first. It is important to make this application promptly, when the weed seedlings are first sighted or the vetch regrowth begins to threaten the tomato plants. An additional postemergence application of a registered grass herbicide may be necessary to control late-emerging grass weeds. Consult product labels for specific information.

In all likelihood, disease and insect control will require fungicides and insecticides. Use of an integrated pest management program can reduce the number of applications. And, use of proper rotations is essential for preventing the build-up of pest populations. Consult your local extension office for information.

Tomato plants grown in hairy vetch mulch continue to produce 2 to 3 weeks longer than those grown conventionally in black polyethylene (fig. 8). This extension of the production season contributes to high yields and profitability (table 3).

Table 3. Yields of fresh-market tomatoes grown in bare soil, black polyethylene, and hairy vetch mulches

	Yield (tons/acre)		
Year	Bare soil	Black polyethylene	Hairy vetch
1991	40.5	43.3	52.2
1992	14.6	17.8	34.8
1993	30.0	33.2	35.2
1994	–*	26.3	37.6
1995	–	36.0	42.1
1996	–	25.9	30.8
Mean	28.4	30.4	38.8

* — = This treatment was not included due to low yields the previous year.

Table 4. Production costs and profits of fresh-market tomatoes grown in black polyethylene and hairy vetch mulches in Beltsville, Maryland, 1991–93

	Black polyethylene	Hairy vetch mulch
Cost or profit	$/acre	
Production cost	$ 2,908*	$ 2,535
Harvest and marketing	8,141	10,290
Total cost	**11,049**	**12,825**
Gross return	17,006†	22,691
Marginal profit	**5,957**	**9,866**

*Average cost of 3 years of production (1991–93).
†Figure from two local cooperatives (1991–93).

Table 4 shows a 3-year average of the production cost, gross returns, and marginal profits for each type of system. The marginal profits of tomatoes grown in hairy vetch average over $3,900 more per acre than those grown in black polyethylene.

Figure 9. ***Laying polyethylene mulch is a costly operation that requires labor and special equipment.***

This difference is partly due to higher yield and partly to reduced production costs by eliminating the expensive plastic mulch and by reducing fertilizer and herbicide use (fig. 9)

Customizing the Basic System

Other Crops

Hairy vetch and other winter annual cover crops are most effective when used with summer vegetables. Early spring vegetables don't work as well in this system. Not only does the mulch delay the soil from warming in spring, but by the time spring vegetables need to be planted, the mulch's biomass is not yet sufficient. Fall vegetables are equally unsuited, since by that time of year, vetch has long since died and the remains have almost completely decomposed.

Large-seeded summer vegetables such as sweet corn, snap beans, and pumpkins are well suited for planting directly through mulch residues with a no-tillage seeder (fig. 10). For direct-seeded vegetables, the cover crop should be planted onto a flat seedbed rather than raised beds. Management of the cover crop before planting includes a choice either of killing with a herbicide or killing with a mower or roller as described for tomatoes. When registered postemergence herbicides are available, delay application of the herbicide and use it only as needed. A hairy vetch cover crop will supply most of the nitrogen requirement for these crops, so commercial nitrogen need only be applied by sidedressing when needed. Cover crop

Figure 10. **A six-row no-tillage seeder planting snap beans.**

residue also can keep crops such as pumpkins or snap beans cleaner than production on bare soil.

Without tillage, small-seeded vegetables are difficult to establish by direct seeding through cover crop residue. Transplanting is a better alternative. The lack of effective herbicides for controlling mulch regrowth or escaped weeds limits the application of this system with many vegetables. In these cases, cover crop combinations, as described below, may be the best way to reduce the need for herbicides.

Cover Crop Alternatives

An ideal cover crop varies from region to region, farm to farm, and even from site to site within a farm. Selection may hinge on factors such as controlling erosion, capturing nitrogen in the fall, releasing nitrogen to the crop, improving the soil structure, and suppressing weeds.

If planning to grow a crop with high *nitrogen requirements* such as tomatoes or sweet corn, a

cover crop such as hairy vetch or crimson clover whose residues decompose and release nutrients within 1 month is most suitable (fig. 11). Yet full-season vegetable crops also require a cover crop whose residues *decompose slowly* and suppress weeds over a longer period.

If *erosion* is the primary concern, a fast-growing cover crop, such as rye, that rapidly forms an aboveground cover and an extensive root system is most effective in stopping soil erosion and capturing remaining nutrients.

To combine benefits such as *erosion control, nitrogen fixation, and slow decomposition* consider combining two or more cover crops into one stand. Combinations that have been found to work well in the mid-Atlantic states are hairy vetch plus rye or hairy vetch plus crimson clover plus rye (see table 2). Rye's early overground growth and root growth make it effective in protecting the soil

Figure 11. **Crimson clover fixes nitrogen, produces organic matter, and attracts beneficial insects.**

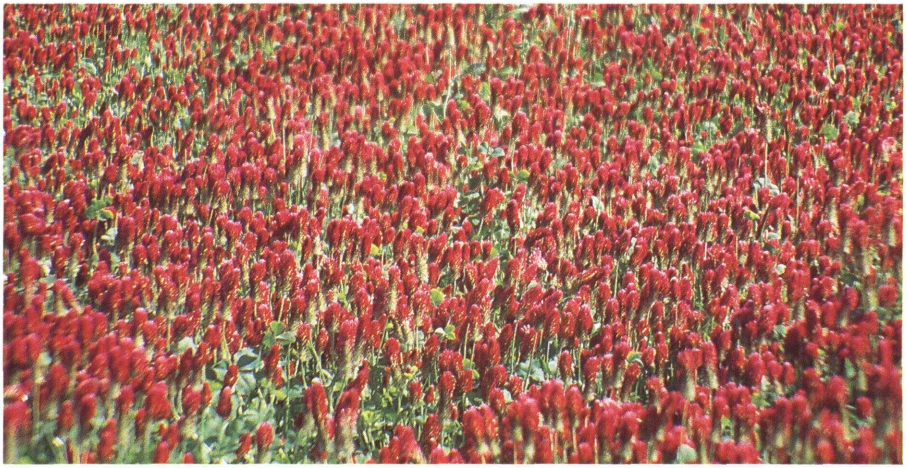
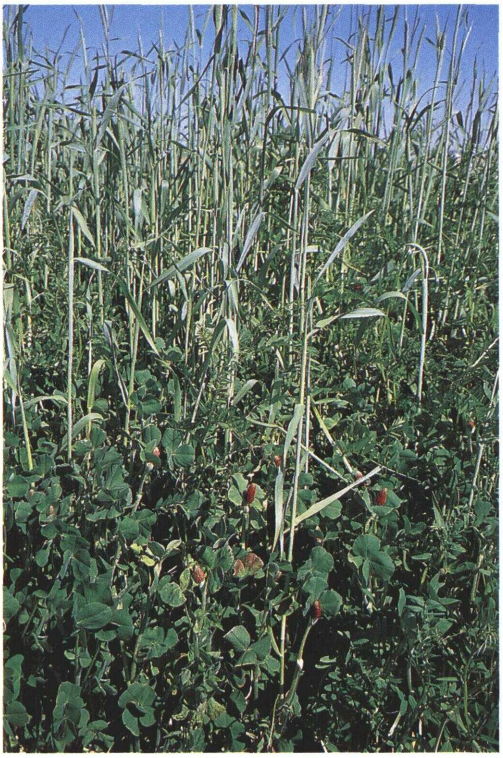


Figure 12. **A combination of hairy vetch, crimson clover, and rye provides a thicker stand, which prevents soil erosion.**



from erosion and in intercepting leftover nutrients from the previous vegetable crop (fig. 12). The hairy vetch and crimson clover combination offers the advantage of fixing nitrogen. As mentioned, mulch from the succulent vetch plant decomposes rapidly and releases nutrients, whereas mulch from rye decomposes slowly and provides weed suppression over a longer period of the growing season.

When planted in combination, hairy vetch and rye should be seeded at the same rate. For example, if vetch is seeded at 40 pounds per acre, then rye should not exceed 40 pounds per acre to keep it from dominating the mixture. Crimson clover should be seeded at 10–12 pounds per acre if added to the vetch-plus-rye mixture. Because of differences in seed size, making one pass for each type of seed provides better uniformity than mixing the seeds and planting in one pass over the field. Properly seeded combinations yield more biomass and maintain high nutrient levels (table 2).

If *weeds* are a concern, using cover crop mixtures and killing by rolling can improve weed suppression. Research has shown that a mixture of hairy vetch plus rye plus crimson clover produces a thicker, more persistent layer of mulch that suppresses weeds more efficiently than hairy vetch alone. Cover crops that are rolled rather than mowed persist longer and extend the duration of weed suppression. Some weeds, particularly perennial or winter annual weeds, can still escape this mixture, however, requiring additional management.

Bear in mind that the performance of many potential cover crop species and combinations and killing methods have not been fully explored. The authors encourage growers to experiment on a small scale and report their results, so they can be incorporated into future recommendations.

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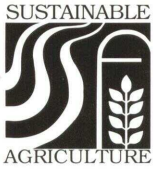

Sustainability in Agriculture

In its simplest sense, sustainable agriculture is profitable crop production that builds soil resources and prevents environmental contamination. Sustainability involves social, economic, and ecological relationships at local, national, and global levels. It encompasses the interrelatedness of all parts of the farming system, including farmers and their families. Sustainable agriculture underscores the importance of the many biological balances in the system and the need to minimize use of material and practices that disrupt these relationships.

Many sustainable practices are not new but, rather, rediscoveries of some of the oldest ways to grow food. Some of the agricultural production areas of the Old World, including the Nile Delta of ancient Egypt, the delta of the Euphrates and Tigris Rivers of Mesopotamia, and the coastal plains of ancient Greece and Rome, are as productive today as they were several thousand years ago. Despite continuous, intensive land use, sustainability has continued to the present day—unequivocal evidence that sustainability can be preserved indefinitely if proper farming practices are adopted.

*The goal of sustainability is to conserve, build, and maintain the soil at a high level of fertility. Farmers in ancient farming communities realized this fact many centuries before the chemical era dominated what is now known as modern agriculture. Amendments that were available to farmers for improving soil fertility were limited to legume cover crops and animal manures, both of which were renewable farm products. Farmers in ancient Egypt, Greece, and Rome used such legumes as faba beans (*Vicia faba*), vetch (*Vicia *species*), and lupins (*Lupinus *species) as important cover crops in their grain production rotations. These cover crops protected soils from erosion, provided seasonal feed for farm animals, and when plowed under enriched the soil with nutrients and organic matter.*

Settlers in the New World seldom used legume cover crops because they selected fertile land for farming. In less than two centuries of poor management, many farms lost their fertility. Under the present system of production, over 40 percent of the cultivable land in the United States is losing topsoil at annual rates exceeding 5 tons per acre. Such rates are considered unsustainable. Only by returning to sustainable agricultural practices will we reverse the trend toward losing topsoil and declining fertility.